Evaluation Of Environmental Protection Policy Implementation Effects in Yangtze River Economic Belt Based on Entropy-Weighted Grey Relation Analysis

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Abstract. To examine the effect of environmental protection policy implementation in the Yangtze River Economic Belt, an indicator system is constructed with resource utilization, environmental management and eco-environment protection as the primary indicators, 17 secondary indicators are selected to reflect the effect of environmental protection policy implementation and a new model is constructed by using the entropy weight method to calculate the weight of each indicator and combining it with the grey relation analysis to examine the effect of environmental protection policy implementation in nine provinces in the upper, middle and lower reaches of the Yangtze River Economic Belt from 2016 to 2020. An empirical analysis was conducted. The results show that from 2016 to 2020, in terms of resource utilization, the implementation effect of environmental protection policies in the midstream provinces of the Yangtze River is better than that in the upstream and downstream provinces of the Yangtze River; in terms of environmental management, the effect of environmental protection policies in the midstream provinces of the Yangtze River is the best, the upstream provinces are the second best, and the downstream provinces are the worst; in terms of ecological protection, the implementation effect of policies in the downstream provinces of the Yangtze River is better than that in the midstream provinces of the Yangtze River, and the upstream provinces are the worst; from the perspective of the overall score of policy implementation effect, the midstream provinces are better than the downstream provinces, and the downstream provinces are better than the upstream provinces. In this regard, the water resource utilization rate of the upstream and midstream provinces and cities of the Yangtze River should be strengthened, vegetation protection and soil and water conservation of the downstream and midstream provinces and cities of the Yangtze River should be enhanced, air and water pollution control of the upstream and downstream provinces and cities of the Yangtze River should be increased, and the ecological resilience of the provinces and cities of the Yangtze River Economic Belt should be improved.

Keywords: Yangtze River Economic Belt; environmental policy; entropy-weight; grey relation analysis; resilient governance; policy innovation.

1. Introduction

The Yangtze River Economic Belt covers 11 provinces and cities, including Shanghai, Jiangsu, Zhejiang, Anhui, Jiangxi, Hubei, Hunan, Chongqing, Sichuan, Yunnan, and Guizhou, with an area of about 2,052,300 square kilometers, accounting for 21.4% of the country and more than 40% of the country's population and gross domestic product. As one of the "three strategies" implemented by the central government, the Yangtze River Economic Zone is a globally influential inland economic zone [1], which spans the three regions of East and West China. As one of the key regional development plans in China, the Yangtze River Economic Zone not only assumes essential economic development functions but also assumes important ecological civilization construction functions. Upholding the concept of "green water and green mountains are the silver mountain of gold", the Yangtze River Economic Zone has implemented many environmental protection policies in recent years to promote the healthy development of ecological civilization.

In November 2021, the "Guidance on the Implementation of "Three Lines and One List" Ecological Environment Zoning Control (Trial)" was released. Since then, eleven provinces and cities along the Yangtze River have completed the release and implementation of ecological environment zoning control programs, establishing an ecological environment zoning control system. In

September 2022, the "Opinions of the State Council of the Central Committee of the Communist Party of China on Deeply Fighting the Battle of Pollution Prevention and Control" put forward many ecological and environmental protection requirements, key tasks for the Yangtze River. The general conditions, key tasks and safeguard measures for environmental protection are being implemented gradually. At present, China has introduced a large number of policies to promote the development of ecological civilization. From the above overview, it can be seen that various policies and specific implementation plans include measures such as control of pollution sources, implementation of regional responsibility division, structured management of drinking water resources, and resource utilization of waste.

Since the 1980s, policy evaluation has only emerged as an independent discipline in China [2], with a late start, and most of the research on the assessment of relevant environmental policies, scholars have established indicator systems and used evaluation methods to construct models for empirical analysis. Xuna (2005) proposed an evaluation index system containing three levels: overall effectiveness, water supply security and water utilization efficiency, and used the comprehensive index and fuzzy comprehensive evaluation method to evaluate the implementation effects and benefits of water resources planning in the Haihe River basin and make recommendations for them [3]; Zhang Baoxue and Chen Qingmei et al. (2020) identified representative indicators from the economic, social, and ecological environment aspects of ecological construction, used the entropy weight method and functional type analysis to dynamically evaluate the ecological structure of the Yangtze River Economic Belt, and analyzed the development trend of ecological construction in each region from 2006-2017 [4]; Kang (2021) studied the economic toughness of the Yangtze River Economic Belt, constructed a comprehensive evaluation index system for the economic toughness of the Yangtze River Economic Belt, and proposed corresponding countermeasures to improve the economic toughness [5]. Qian Yucheng (2019) studied the evaluation of the quality of the agricultural ecological environment in the Yangtze River Economic Belt, constructed an agricultural ecological environment index system, and proposed targeted policies for the restoration of the agricultural ecological environment in the Yangtze River Economic Belt in combination with the evaluation method [6]. In general, the existing literature on the implementation effect of environmental protection policies is the most qualitative evaluation from statistical analysis of data, and few articles are based on quantitative analysis and evaluation on the evaluation method model, and no unified, comprehensive evaluation system has been formed for the review of environmental protection policies. Therefore, the author constructs an indicator system with resource utilization, environmental management and ecological, environmental protection as the primary indicators, selects 17 secondary indicators that can reflect the effect of environmental protection policy implementation, calculates the weight of each indicator using the entropy weighting method and combines it with the grey relation analysis to construct a new model to empirically analyze the effect of environmental protection policy implementation in nine provinces in the upper, middle and lower reaches of the Yangtze River economic belt from 2016 to 2020, and in response to the evaluation results. A series of meaningful future environmental protection policy optimization solutions are proposed in response to the evaluation results.

2. Data Sources And Research Methods

2.1. Data sources

Nine provinces covered by the Yangtze River Economic Belt (Jiangsu, Zhejiang, Jiangxi, Anhui, Hunan, Hubei, Yunnan, Sichuan, and Guizhou) were used as the research objects to analyze the effect of environmental protection policy implementation in the Yangtze River Economic Belt. Based on the theories related to environmental protection policies and data availability, panel data on the implementation effects of environmental protection policies in nine provinces of the Yangtze River Economic Belt from 2016 to 2020 were selected. All data were obtained from the Statistical Yearbook, the Ecological and Environmental Status Bulletin, the Water Resources Bulletin, and the National

Economic and Social Development Statistical Bulletin of the nine provinces in the Yangtze River Economic Belt from 2016 to 2020, and individual data were missing according to the linear interpolation method to fill in.

2.2. Research methods

The main research methods used in this paper include the literature, empirical, and comparative research methods. The literature research method is mainly to review the literature to sort out the concepts and theories closely related to the environmental protection try effect evaluation method, and analyze and construct a comprehensive evaluation method of environmental protection policy implementation effect in the Yangtze River Economic Zone. The empirical research method is based on the premise of determining a set of indicator systems for the evaluation object, first using the entropy value method to determine the weights and then combining it with the grey relation analysis method to determine the grey relation degree (the comprehensive score of environmental protection policies) for each province in each year. The comparative study method is to calculate the total environmental evaluation scores of each province in the Yangtze River Economic Belt through the entropy value method and the grey relation analysis method after the construction of indicators and data collection and to conduct a horizontal comparative analysis of the total scores and the weighting results of the secondary indicators of each province to obtain the current ranking of the implementation effect of environmental policies in nine provinces in the Yangtze River Economic Belt; at the same time, the evaluation results of each province and city are analyzed in the time series for vertical comparison to obtaining the evaluation results of each province, and city are also compared longitudinally in a time series to accept the changes in environmental quality and sub-aspect scores of each province and city and analyze the change trends. Finally, suggestions for improving environmental protection policies in the Yangtze River Economic Belt are proposed under the perspective of resilient development.

3. Grey Relation Model With Embedded Entropy Weights

3.1. Selection of evaluation indicators

The scientific evaluation indicator system is the premise and basis for the practical evaluation of policy implementation. The primary purpose of establishing the Yangtze River Economic Zone environmental protection evaluation index system is to scientifically judge and analyze the implementation effect of the policy through the index system and objectively reflect the implementation of environmental protection policies and the degree of play. At present, China is in the process of accelerated industrialization and urbanization and is facing substantial environmental pressure along with rapid economic growth. The Outline of the Yangtze River Economic Belt Development Plan puts forward the protection and restoration of water resources, water environment, water ecology, and other resources as the primary mark to define the improvement status of the ecological environment in the Yangtze River Economic Belt. In this study, with the help of ROSTXM6 text mining software, the six policy samples were subjected to word separation processing, word frequency analysis, and word frequency statistics. On this basis, the co-occurrence matrix of commonplace subject words was imported into the UCINET tool to obtain a social network map of high-frequency words for environmental protection policies in the Yangtze River Economic Belt, as shown in Fig. 1.

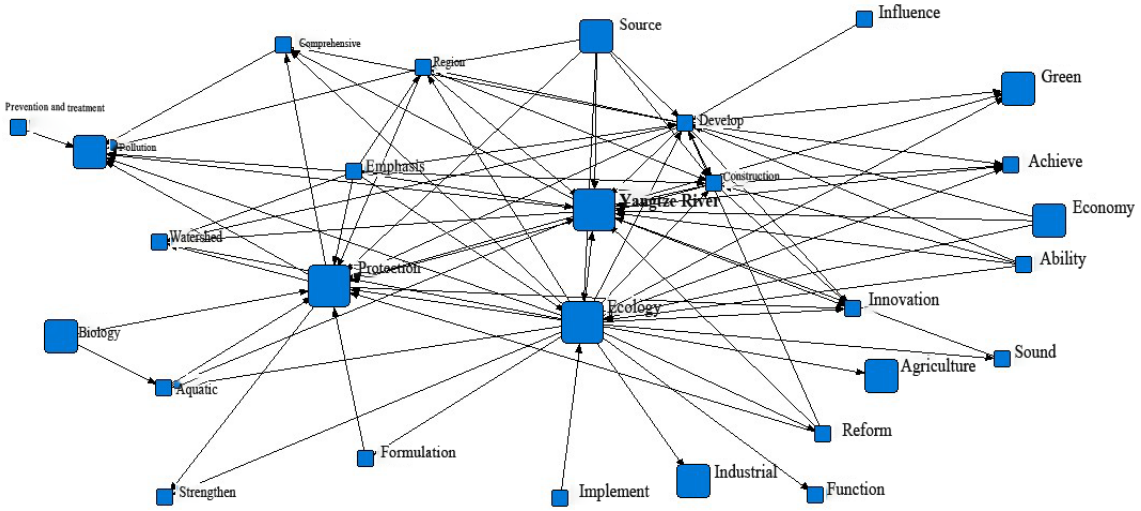


Fig. 1 Social network mapping of high-frequency words co-occurring in environmental policies in the Yangtze River Economic Belt

The size of the square nodes in Figure 1 represents the frequency of the topic words, and the node cut lines represent the closeness between the keywords. It can be seen that the words "Yangtze River", "ecology", and "protection" are the keywords "green", "pollution," "biological," "agriculture," "industry," "resources," and "economy" as keywords. "economy" are secondary keywords. Based on the summary and classification of the above keywords, we also refer to the 13th Five-Year Plan, the Ecological and Environmental Protection Plan for the Yangtze River Economic Belt, the 13th Five-Year Plan for National Economic and Social Development, the Opinions of the State Council of the Central Committee of the Communist Party of China on Accelerating the Construction of Ecological Civilization, and other resource and environmental plans. The final decision was made to focus on three segments: resource utilization, environmental management, and ecological protection. Considering the scientific, feasibility and representativeness of indicator selection, the availability of indicator data, and the systemic nature of the evaluation system [7], the specific indicators that can reflect the efficiency of resource utilization, the effectiveness of environmental management, and ecological protection were selected to characterize the implementation of environmental protection policies in the Yangtze River Economic Zone, i.e., three primary indicators and eighteen secondary indicators, taking into account the specific implementation of environmental protection policies in the Yangtze River Economic Zone. The particular index system framework is shown in Table 1 below. The specific framework of the indicator system is shown in Table 1 below.

Table. 1 Evaluation index system of environmental protection policy implementation effectiveness in Yangtze River Economic Zone

Tier 1 Indicators	Tier 2 Indicators	Indicator Unit	Indicator Trend
Resource Utilization	Growth rate of total energy consumption X_1	%	Negative
	Growth rate of effective utilization coefficient of irrigation water on farmland X_2	%	Positive
	Total water consumption growth rate X_3	%	Negative
	Water consumption reduction rate of 10,000 Yuan GDP X_4	%	Positive
	Arable land area growth rate X_5	%	Positive
	General industrial solid waste comprehensive utilization rate X_6	%	Positive
Environmental Governance	Industrial COD emissions reduction rate X_7	% (kg/million yuan)	Positive
	Reduction rate of industrial ammonia nitrogen emissions X_8	% (kg/million yuan)	Positive
	Industrial sulfur dioxide emissions reduction rate X_9	% (kg/million yuan)	Positive
	Reduction rate of industrial solid waste generation X_{10}	% (kg/million yuan)	Positive
	Water function zone compliance rate of important rivers and lakes X_{11}	%	Positive
	Proportion of state-controlled cross-sections (points) reaching or better than Class III water quality X_{12}	%	Positive
	Centralized sewage treatment rate X_{13}	%	Positive
Ecological Protection	Forest cover X_{14}	%	Positive
	Forest stock X_{15}	Billion cubic meters	Positive
	Nature reserve area as a proportion of the jurisdictional area X_{16}	%	Positive
	New soil erosion control area X_{17}	% (thousand hectares)	Positive

3.2. Entropy method

Noting the natural environment of policy implementation effect evaluation, too many factors directly or indirectly affect the final review of the policy implementation effect. Therefore, a reasonable theoretical approach is needed for its study. The concept of entropy value in information theory is cited here, and the mathematical model of the entropy value method is established for the subsequent in-depth analysis.

The entropy in information theory is invoked to measure uncertainty, and the randomness and needlessness of the scheme are estimated by calculating the entropy value. Since entropy can also judge the dispersion of indicators, it can also be used to evaluate the variability of indicators, thus providing a basis for the indicator weights of comprehensive evaluation [8].

The entropy method first standardizes the indicators and subsequently substitutes them into the comprehensive evaluation function for calculation.

Suppose there exists data in a matrix with i rows and j columns, which are divided into two ways of processing according to the nature of the data.

If the nature of the indicator is positive, then there is a normalization formula:

$$X_{ij} = \frac{X_{ij} - min\{X_i\}}{max\{X_i\} - min\{X_i\}}$$

If the nature of the indicator is negative, then there is a normalized formula:

$$X_{ij} = \frac{min\{X_i\} - X_{ij}}{max\{X_i\} - min\{X_i\}}$$

After the index standardization work is completed, the proportion of the index value of item j in the area i can be calculated. There is a formula for calculating the ratio:

$$Y_{ij} = \frac{X_{ij}}{\sum_{i=1}^{m} X_{ij}}$$

Calculate the j index information entropy by using the results of the proportion calculation formula, and then calculate the redundancy of the relevant information entropy. After calculating all the sameness, the appropriate weights are calculated separately. There are related formulas:

$$e_j = -k \sum_{i=}^{m} Y_{ij} \ln Y_{ij}$$

$$d_j = 1 - e_j$$

$$W_j = \frac{d_j}{\sum_{i=1}^{n} d_j}$$

3.3. Grey relation analysis

The grey relation analysis method judges the difference and degree of relation between different series through the geometric shape of the curve formed by the systematic statistical series. The closer the curve is, the greater the degree of relation between the corresponding series and the greater the development trend between the two factors. One [9]. The idea is to transform the discrete behavior observations of system factors into piecewise continuous polylines through linear interpolation and then construct a model to measure the degree of association according to the geometric features of the polylines [10]. Compared with other mathematical statistical analysis methods, such as regression analysis and principal component analysis, the grey relation method has no strict requirements on the number and regularity of samples [11].

Because the data dimensionless has been completed in the entropy method, the reference and comparison sequences are first defined here. In the grey relation analysis method, the optimal value of the dimensionless data of each index is the reference sequence, that is, Y_{i0}, both of which are 1; the dimensionless sample data is used as the comparison sequence, that is, Y_{ij}.

Computes the absolute difference between a reference sequence and a comparison sequence. Let Δij be the fundamental difference between Y_{i0} and Y_{ij}, the calculation formula is:

$$\Delta_{ij} = \left| Y_{i0} - Y_{ij} \right|$$

Then calculate the grey relation coefficient; the calculation formula of the grey relation coefficient is as follows:

$$r_{ij}=\Delta_{min}+\rho\Delta_{max}\Big/\rho\Delta_{max+}\Delta_{ij}$$

Among them, Δ_{min} and Δ_{max} represent the minimum value and maximum value of all absolute differences Δij respectively, ρ is the resolution coefficient, 0<ρ<1, generally ρ=0.5. Obtain the absolute difference Δ_{ij} in which the minimum value is 0 and t,he maximum value is 1, and then obtain the grey relation coefficient. The grey relation degree is calculated based on the weight of each index and the grey relation coefficient, the ; thela is as follows:

$$r_i=\sum_{i=1}^{m} r_{ij}W_{ij}$$

4. Application Of Policy Implementation Effect Evaluation Methods

4.1. Determination of indicator weighting coefficients

According to the indicators determined above, the 2016-2020 indicator data of 9 provinces in the Yangtze River Economic Belt are selected to investigate the implementation effect of environmental protection policies in the Yangtze River Economic Belt. Standardized formulas are adopted for the selected positive and negative indicators, and then the data is preprocessed according to the dimensionless formula. After the standardized matrix is obtained, the entropy weight and weight are obtained using the entropy weight method [12]. The entropy weight of 17 indicators Weight e_{xi}=(0.9009, 0.8311, 0.8756, 0.8381, 0.8461, 0.8404, 0.8822, 0.9032, 0.9043, 0.8685, 0.9010, 0.8907, 0.9255, 0.9139, 0.7396, 0.8248, 0.8 004).

Seventeen index weights W_{ij}=(0.0427, 0.0701, 0.0532, 0.0702, 0.0650, 0.0690, 0.0513, 0.0431, 0.0424, 0.0548, 0.0427, 0.0482, 0.0326, 0.0378, 0.1141, 0.0757, 0.0872), as shown in Table 2.

Table. 2 Information entropy and weights of the seventeen secondary indicators

Indicators	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}
Information entropy	0.9009	0.8311	0.8756	0.8381	0.8461	0.8404	0.8822	0.9032	0.9043	0.8685	0.9010	0.8907	0.9255	0.9139	0.7396	0.8248	0.8004
Weights	0.0427	0.0701	0.0532	0.0702	0.065	0.069	0.0513	0.0431	0.0424	0.0548	0.0427	0.0482	0.0326	0.0378	0.1141	0.0757	0.0872

4.2. Calculation of grey relation and composite score

Based on the indicator data from 2016-2020, a grey relation analysis was conducted to derive the scores of Sichuan, Hubei, Jiangsu, Zhejiang, Anhui, Jiangxi, Hunan, Yunnan, and Guizhou provinces in resource use, environmental management, ecological protection, and overall grey relation (composite score) for these five years. The scores are shown in Table 3 below.

Table. 3 Comprehensive score of policy implementation effect

Province	Year	Resource Utilization	Environmental Governance	Ecological Protection	Grey relation (composite score)
Sichuan Province	2016	0.1700	0.1821	0.2161	0.5681
	2017	0.1627	0.1710	0.2174	0.5511
	2018	0.1957	0.1736	0.2824	0.6517
	2019	0.1592	0.1951	0.2428	0.5972
	2020	0.1991	0.2404	0.2505	0.6900
Hubei Province	2016	0.1892	0.2236	0.1210	0.5339
	2017	0.1721	0.1968	0.1215	0.4904
	2018	0.1690	0.1714	0.1296	0.4700
	2019	0.1659	0.1886	0.1284	0.4828
	2020	0.1781	0.2129	0.1281	0.5191
Jiangsu Province	2016	0.1882	0.1281	0.1063	0.4226
	2017	0.2075	0.1687	0.1062	0.4824
	2018	0.2510	0.1597	0.1062	0.5168
	2019	0.1914	0.1685	0.1062	0.4660
	2020	0.2231	0.2067	0.1062	0.5360
Zhejiang Province	2016	0.2009	0.1857	0.1257	0.5123
	2017	0.1963	0.1746	0.1255	0.4964
	2018	0.2118	0.1739	0.1278	0.5135
	2019	0.2119	0.2010	0.1279	0.5407
	2020	0.2284	0.2318	0.1279	0.5882
Anhui Province	2016	0.1886	0.1898	0.1115	0.4898
	2017	0.1989	0.1726	0.1116	0.4831
	2018	0.2029	0.1535	0.1126	0.4690
	2019	0.2119	0.1588	0.1145	0.4852
	2020	0.1868	0.1900	0.1139	0.4907
Jiangxi Province	2016	0.1661	0.1760	0.1372	0.4793
	2017	0.1651	0.1928	0.1368	0.4947
	2018	0.1649	0.1879	0.1460	0.4988
	2019	0.1645	0.1897	0.1415	0.4957
	2020	0.1751	0.2299	0.1426	0.5475
Hunan Province	2016	0.1849	0.1791	0.1288	0.4927
	2017	0.1919	0.2147	0.1276	0.5343
	2018	0.1873	0.1826	0.1349	0.5049
	2019	0.1837	0.2140	0.1390	0.5368
	2020	0.2013	0.2601	0.1395	0.6009
Yunnan Province	2016	0.1714	0.1914	0.1667	0.5295
	2017	0.1558	0.1994	0.1677	0.5229
	2018	0.1700	0.1604	0.1794	0.5098
	2019	0.2047	0.1629	0.1900	0.5576
	2020	0.1544	0.2128	0.1858	0.5530
Guizhou Province	2016	0.1719	0.2180	0.1355	0.5254
	2017	0.1740	0.1743	0.1378	0.4861
	2018	0.1790	0.1677	0.1411	0.4878
	2019	0.1640	0.1989	0.1446	0.5075
	2020	0.2455	0.2323	0.1453	0.6231

5. Data Analysis

5.1. Comprehensive rating data cross-sectional comparison analysis

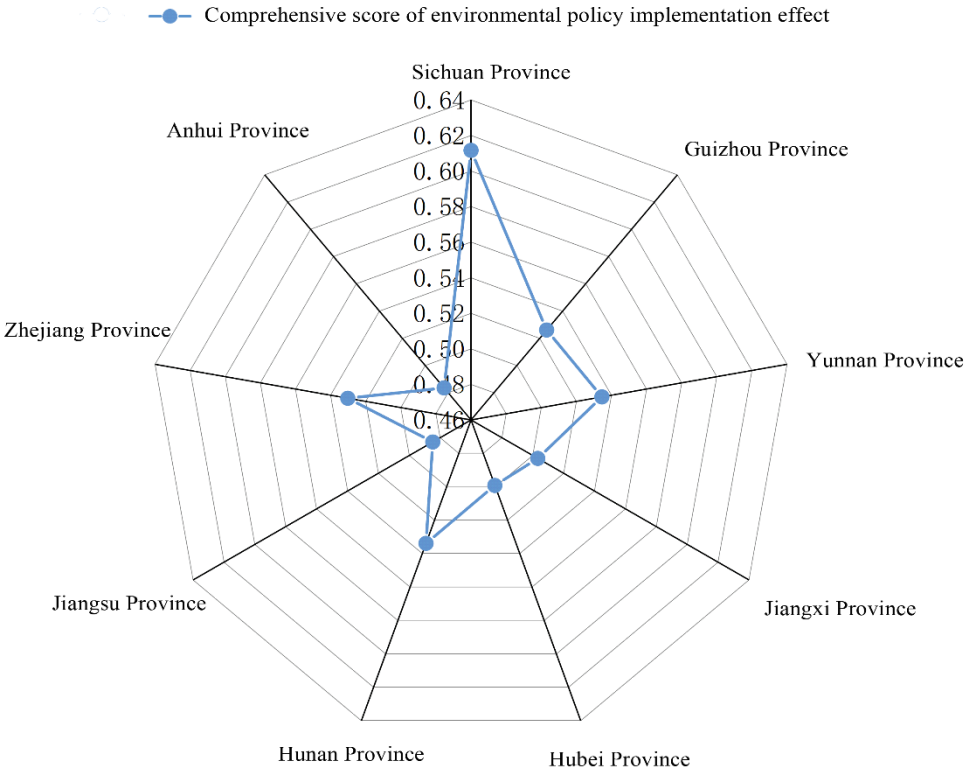


Fig. 2 Average score of environmental policy implementation effects in nine provinces of the Yangtze River Economic Belt from 2016-2020

Fig. 2 shows the average scores of environmental protection policy implementation effects in nine provinces on the Yangtze River Economic Belt from 2016 to 2020. The calculation shows that Sichuan Province has the highest annual average score of 0.6116, followed by Yunnan Province, Hunan Province, Zhejiang Province, Guizhou Province, Jiangxi Province, Hubei Province, Jiangsu Province, and lastly Anhui Province with a score of 0.4835; the upstream provinces of the Yangtze River (Sichuan, Guizhou, and Yunnan) have an average score of 0.3101, the midstream provinces (Jiangxi, Hubei, and Hunan) have an average score of 0.5121 To a certain extent, this reflects the gap between the implementation of environmental policies in the upper, middle and lower reaches of the Yangtze River (midstream provinces are better than downstream provinces, and downstream provinces are better than upstream provinces), the ecological protection and restoration work still has a long way to go. The coordinated development of the river basin needs to be strengthened.

5.2. Longitudinal comparison analysis of comprehensive rating data

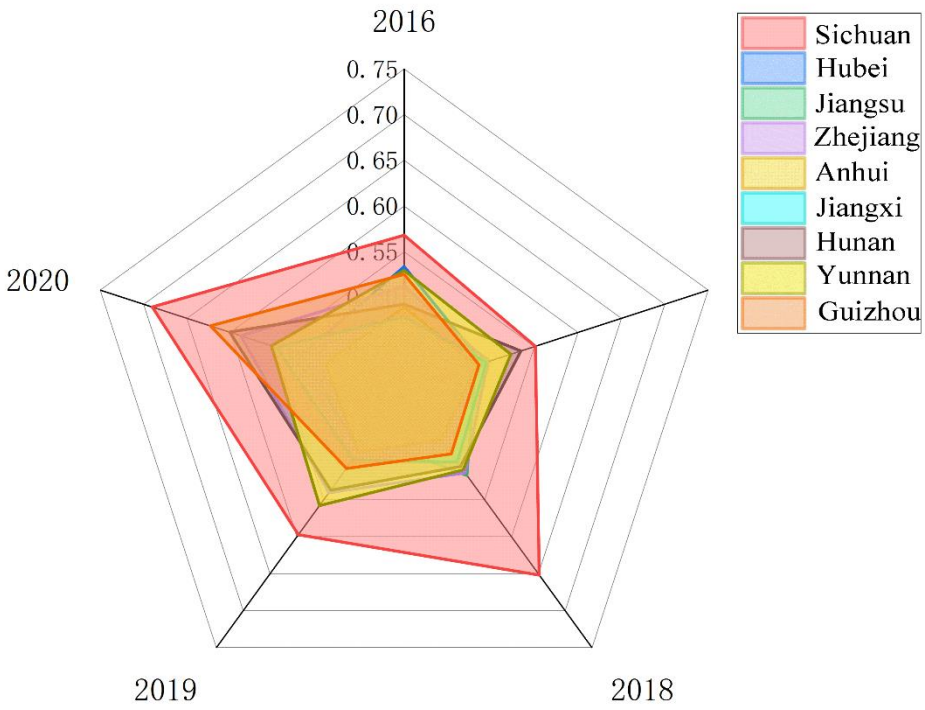


Fig. 3 Longitudinal comparison of data from nine provinces in the Yangtze River Economic Belt

As can be seen from Figure 3, the overall score of environmental policy implementation effect in Sichuan Province is always in the first place, indicating that Sichuan Province has the best environmental policy implementation effect, and other provinces need to actively learn from Sichuan Province; the overall score of environmental policy in Hubei Province, Jiangsu Province and Hunan Province is unstable, indicating that these three provinces need to always maintain the continuity, stability and sustainability of the policy in the process of environmental policy implementation; in 2018 the eight provinces (except Sichuan Province) all showed a significant inflection point of growth in their composite scores, indicating that in 2018 most provinces in the Yangtze River Economic Belt focused on economic development and neglected the implementation of environmental policies, and after 2018 provinces recognized the importance of the environment and began to introduce and pay attention to the implementation of environmental policies; the composite scores of all provinces in 2020 are slightly higher than the scores in 2016, indicating that the environmental policies of the Yangtze River Economic Belt implementation is working.

5.3. Resource utilization evaluation analysis

Fig.4 shows the annual average resource utilization scores of the nine provinces in the Yangtze River Economic Belt for the five years from 2016 to 2020, while Figure 5 depicts the trend of the resource utilization scores of the first-tier indicators in the environmental protection policy implementation effects of the nine provinces in the Yangtze River Economic Belt from 2016 to 2020. As can be seen from Fig. 4 and Fig. 5, Jiangsu Province has the highest average annual resource utilization score of 0.2122; Jiangxi Province has the lowest average yearly resource utilization score of 0.1671, but there is an emphasis on improving resource utilization to surpass Yunnan Province in 2020. Among them, Jiangsu Province and Yunnan Province fluctuate widely, indicating that the effectiveness of policy implementation in resource utilization is unstable and the stability of policy implementation needs to be maintained; the remaining provinces show an overall increasing trend, indicating that the effectiveness of resource utilization in the Yangtze River Economic Belt provinces is showing a gradual movement toward improvement. In general, the effect of resource utilization in the lower Yangtze River provinces is better than in the upper Yangtze River provinces. In comparison,

the impact of resource utilization in the upper Yangtze River provinces is better than that in the middle Yangtze River provinces.

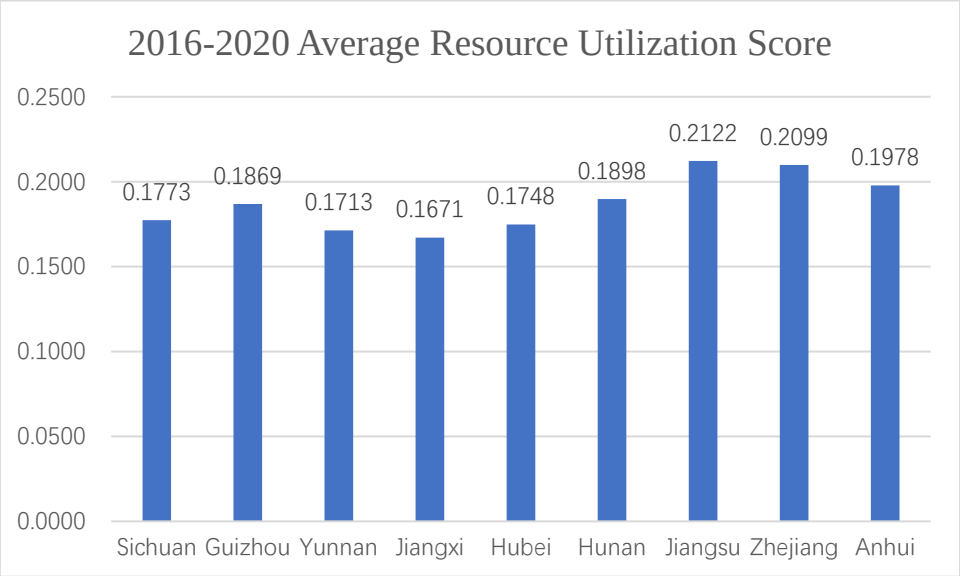


Fig. 4 Yangtze River Economic Zone annual average Resource utilization score

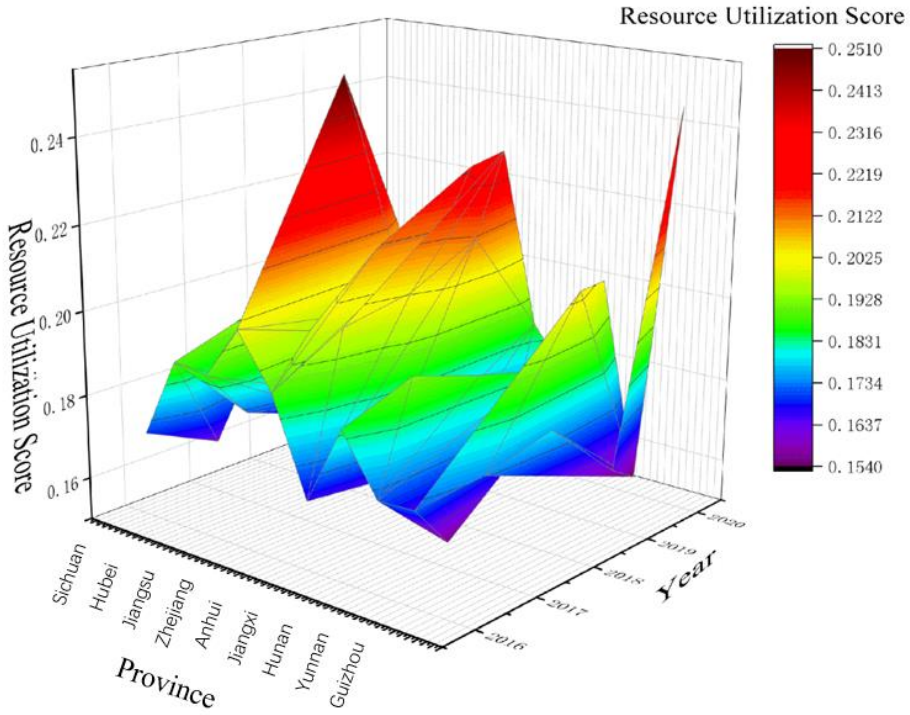


Fig. 5. Resource utilization score of nine provinces in the Yangtze River Economic Belt

5.4. Environmental governance evaluation analysis

Fig. 6 shows the annual average environmental governance scores of the nine Yangtze River Economic Belt provinces for the five years from 2016 to 2020. Figure 7 depicts the trend of the environmental governance scores of the first-tier indicators of the environmental policy implementation effects in the nine Yangtze River Economic Belt provinces from 2016 to 2020. As seen from Figure 6, Hunan Province has the highest average annual environmental governance score, and combined with Fig. 7, it is clear that as a more economically developed region in the middle reaches of the Yangtze River, Hunan Province has been focusing on environmental governance aspects. As can be seen from Figure 7, the environmental governance scores of the provinces in the

Yangtze River Economic Belt have been decreasing before 2018, indicating that the implementation of policies related to environmental governance in the Yangtze River Economic Belt before 2018 has been less effective; after 2018, the environmental governance scores of the nine provinces in the Yangtze River Economic Belt show an upward trend, indicating that the provinces focus on environmental governance aspects after 2018. The data of environmental governance scores in Sichuan, Yunnan and Jiangsu provinces fluctuate widely, meaning that these three provinces need to strengthen the stability of implementing environmental governance-related policies. Overall, in terms of environmental governance, the provinces in the middle reaches of the Yangtze River are better than those in the upper reaches of the Yangtze River, and the provinces in the upper reaches of the Yangtze River are better than those in the lower reaches of the Yangtze River.

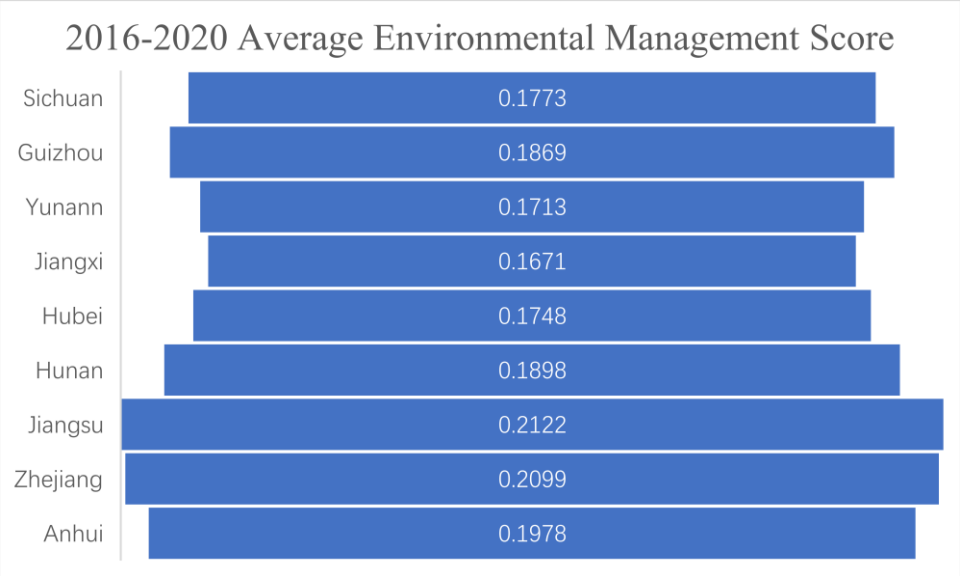


Fig. 6 Yangtze River Economic Zone annual average environmental management score

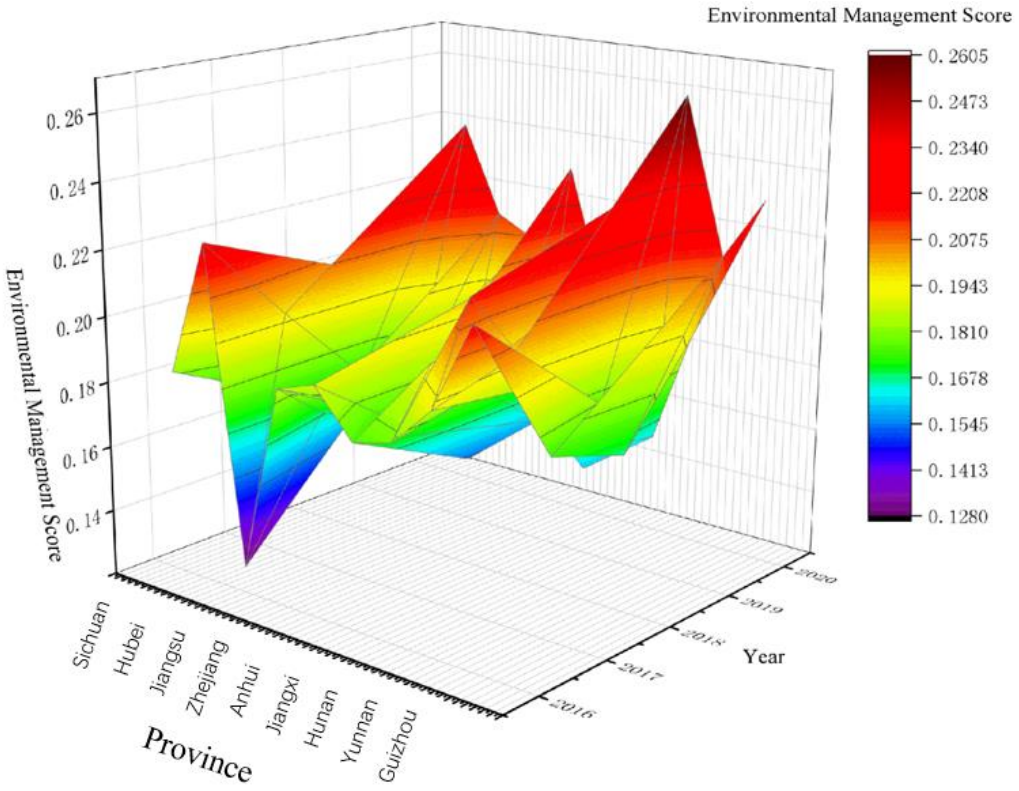


Fig. 7 Environmental management score for nine provinces in the Yangtze River Economic Belt

5.5. Ecological protection evaluation analysis

Fig. 8 shows the annual average ecological protection scores of the nine provinces in the Yangtze River Economic Belt for the five years from 2016 to 2020, and Fig. 9 depicts the changing trend of the ecological protection scores of the first-tier indicators in the implementation effect of environmental protection policies in the nine provinces in the Yangtze River Economic Belt from 2016 to 2020. As can be seen from Fig. 8, Sichuan Province has the highest average annual ecological protection score, with an average score of 0.6116, which, combined with Figure 9, shows that the effectiveness of ecological protection in Sichuan Province is steadily improving; however, Yunnan, Guizhou and Hunan have lower ecological protection scores, and the three provinces lack attention in ecological protection and the process is slow. Overall, in terms of ecological protection, most provinces in the Yangtze River Economic Belt show an increasing trend in their scores, and the ecological protection effectiveness of the lower Yangtze River provinces is better than that of the middle Yangtze River provinces, and the middle Yangtze River provinces are better than the lower Yangtze River provinces.

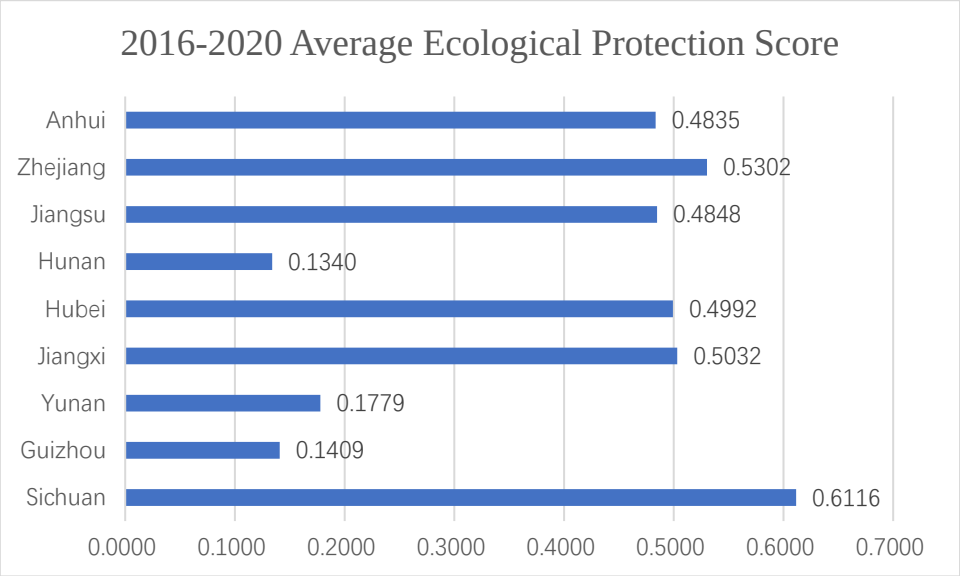


Fig. 8 Annual average ecological protection score of Yangtze River Economic Zone

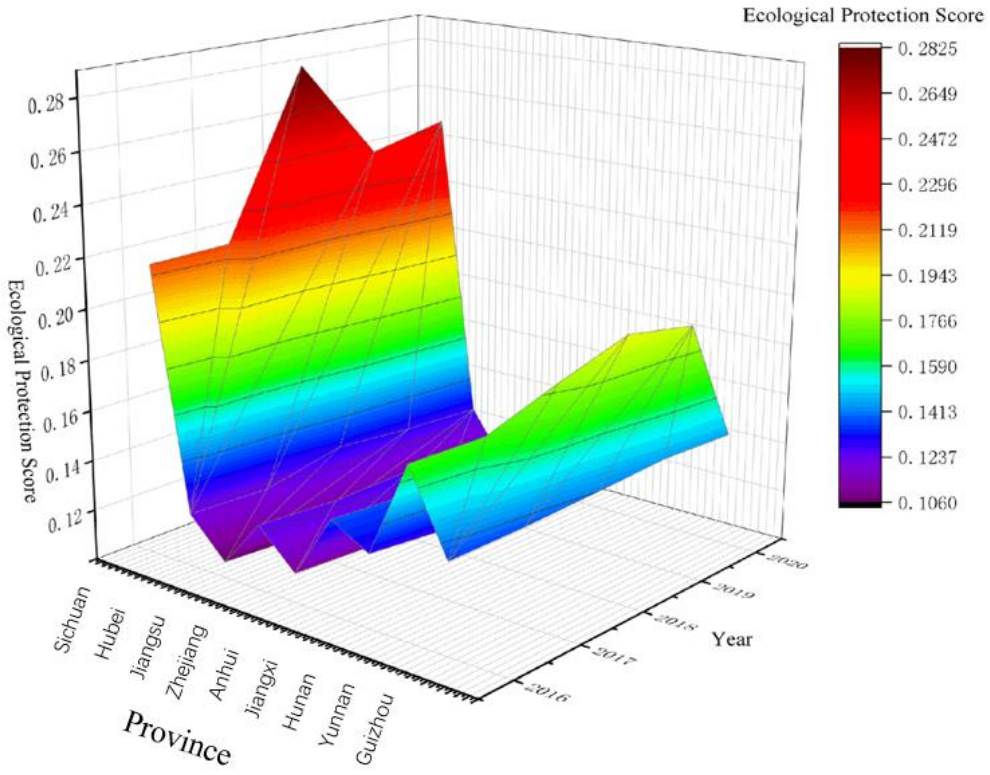


Fig. 9 Ecological protection score of nine provinces in the Yangtze River Economic Belt

6. Suggested Policy Improvements

6.1. Strengthening water resources utilization in the middle reaches of the Yangtze River provinces and cities

According to the analysis results, it can be seen that the provinces in the upper and middle reaches of the Yangtze River have lower scores in resource utilization. Analysis of specific index data shows that the provinces in the Yangtze River economic belt have smaller gaps in arable land area and comprehensive utilization rate of general industrial solid waste. At the same time, there are significant gaps in the utilization efficiency of water resources (growth rate of total water consumption and reduction rate of water consumption of 10,000 Yuan GDP). Based on this, it is recommended to improve the intensive use of water resources in the upper and middle reaches of the river basin as a whole and to achieve a balanced allocation of space. Provinces and cities in the upper and middle reaches of the Yangtze River can include water conservation as a binding indicator in the assessment and evaluation system of water Strengthen water conservation measures, increase water conservation publicity and enhance public awareness of water conservation. Focus on promoting water conservation in the agricultural sector, with water-saving renovation in irrigation areas as the core, and increase the rate of agricultural water conservation. Transform the industrial water use pattern, reasonably increase the price of industrial water use, and improve the utilization rate. Promote sewage discharge by saving water, and promote water saving by limiting sewage discharge to reduce pollutant discharge and effectively protect water resources, to alleviate the contradiction between supply and demand of water resources in some areas of the basin and during the dry season, and guarantee the balance between supply and demand of water resources in the bay.

6.2. Strengthening vegetation protection and soil conservation in the middle and lower reaches of Yangtze River provinces and cities

According to the evaluation and analysis results, the downstream provinces of the middle reaches of the Yangtze River could be better in terms of ecological protection implementation effect. The

specific analysis of index data shows that in terms of forest cover, the vegetation cover of Jiangsu Province, a representative province in the lower reaches of the Yangtze River, is less than half of that of Sichuan Province, a representative province in the upper reaches, and Hubei Province, a representative province in the middle reaches, while the new soil erosion control area is only one-tenth of that of Sichuan Province and one-sixth of that of Hubei Province, and the ratio of protected areas to national land area is relatively low in both Hubei and Jiangsu Provinces.

To a certain extent, this reflects the lack of ecological protection in the middle and lower reaches of the Yangtze River Economic Belt. It is suggested that the provinces and cities along the middle and lower reaches of the river should give priority to protection, strengthen the protection of natural forest and vegetation resources along the river while developing in a reasonable and orderly manner, increase the construction of the Yangtze River ecological barrier system, strengthen the protection of resources in scenic areas along the river, promote the improvement of soil and water conservation infrastructure, and do an excellent job in preventing soil erosion [13]. Provincial governments to develop county (city, district) forest, grass and other vegetation cover annual indicators and assessment standards, and will be included in the ecological civilization construction assessment system and target responsibility system assessment content, timely soil erosion survey, announced to the community to supervise the implementation. People's governments above the county level should organize relevant departments according to the soil erosion situation, divide the key prevention and control areas and critical treatment areas, include them in the areas where construction is prohibited and restricted, and make them public. In the surrounding areas of rivers, lakes, reservoirs, channels, ponds and weirs, roads, etc., the land owners, users or relevant management units obligated to prevent and treat soil erosion shall build vegetation protection zones.

6.3. Increasing air and water pollution control in the provinces and cities upstream and downstream of the Yangtze River

According to the analysis results, the upstream and downstream provinces of the Yangtze River are poor in terms of environmental governance implementation effectiveness; the Yangtze River economic belt has an overall upward trend in environmental governance implementation effectiveness; the upstream such as Sichuan Province has made the most progress, the midstream such as Hubei Province has poor implementation effectiveness, and the downstream such as Jiangsu Province has always had an emphasis on governance issues. At the same time, it can be seen from the data of specific indicators that the reduction rate of industrial chemical oxygen demand, ammonia nitrogen, sulfur dioxide and solid waste emissions in the upper, middle and lower reaches of the Yangtze River tends to decrease year by year; the centralised treatment rate of sewage in the upper reaches of the Yangtze River, such as Sichuan, is low, and the rate of compliance with the water function zone of important rivers and lakes and the proportion of state-controlled cross sections reaching or better than Class III water quality in the lower reaches of the Yangtze River, such as Jiangsu Province, is low. The water pollution problem is more serious. This reflects that upstream and downstream provinces and cities in the Yangtze River economic belt should promote the comprehensive prevention and control of pollution in treating air pollution and consolidate the results. While strengthening the downstream water pollution treatment, the upstream should also pay attention to prevent corrosion to the downstream basin. First of all, people's governments at all levels should gradually increase investment in the protection and comprehensive management of the atmospheric environment and guarantee the funding of atmospheric environmental protection work. City and county level joint prevention and control, strengthen the control of pollution sources, adhere to the "two-handed", both to promote the control of industrial pollution, and from the air pollution and dust management, the implementation of pollution control to specific measures. According to the policy of "who pollutes, who governs", enterprises must invest in the treatment of funds to strengthen the comprehensive prevention and control of air pollution. Second, we should increase the treatment of key industries along the Yangtze River, improve the enforcement of water-related enterprises, strengthen the crackdown on unlicensed discharge and excessive discharge, increase the enthusiasm

for local pollution control, reduce the number of pollutants into the river, and promote the continuous improvement of water quality in the basin. In the upstream and midstream areas, we should strengthen the centralized treatment and recycling of industrial park sewage, actively promote the construction of urban sewage treatment facilities and support pipeline networks to improve the treatment efficiency of existing sewage treatment facilities while taking care not to affect the downstream water quality.

6.4. Improving the ecological resilience of provinces and cities in the Yangtze River Economic Belt

Promote the co-protection of ecological resilience space in the Yangtze River Economic Belt and strengthen collaborative environmental management. The provinces in the Yangtze River Economic Belt differ significantly in resource utilization, ecological management, and environmental protection, and it is necessary to strengthen the exchange of experience and division of labour between provinces and municipalities to improve the ecological environment and the co-preservation and joint governance mechanism [14].

Optimise the ecological resilience development model in each province and city to improve the level of ecological resilience [15]. The analysis of the influencing factors in the previous section shows that the development of each province is uneven, with further industrial development, agricultural levels, natural resources, etc.. Thus it is necessary to designate ecological resilience protection measures with full consideration of the actual effect of each place.

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